NEWS SCIENCE NEWS

"STATIC ELECTRICITY" MISCONCEPTIONS

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Some elementary science textbooks contain subtle errors which pose barriers to students' understanding. "Static electricity" is one subject which is rife with errors. Since the errors in textbooks seem to act like "viruses" which can "infect" our minds, I hope that the following discussion will act as a sort of "antivirus" (grin!). It should help those who read this webpage, and with luck my article might utilise some of the same rumour-dynamics as the viruses. These ideas might take off and spread through the elementary education population and "immunise" large numbers of people against these particular misconceptions.

Electrostatics: not "staticness"

"Static electricity" is not electricity which is static. Instead, it is a collection of different electrical phenomena, where:

- the amounts of positive and negative electric charge within a material are not perfectly equal.
- voltage is high and current is low.
- electrical forces (attraction and repulsion) are seen to reach across space. Widely spaced objects may attract or repel each other. Hair might stand on end!
- electric fields (as opposed to magnetic fields) become very important (electric fields are also called "electrostatic fields" or "e-fields").

Electrostatics is about *charge* and about the attract–repel forces which electric charge creates. The motion or "staticness" of the charge is irrelevant: after all, the forces are still there, even when the charges start flowing. Charges which are separated or imbalanced can sometimes flow along, yet the "static" effects are undiminished when the current begins. In other words, it is perfectly possible to create *flows* of so-called "static" electricity.

It is very misleading to concentrate on the "staticness" of the charges, as it derails our explanations and hides many important concepts such as charge separation, the density of imbalanced positive–negative charge, and the presence of voltage fields surrounding the imbalanced charges. These things are important even when the "static electricity" begins moving along as a current.

Electrostatics is not about "staticness". Instead, it's about charge and forces. Imagine if water was explained just as badly as static electricity. In that case, most people would believe in two special kinds of water called "static water" and "current water". We'd wrongly insist that hydrostatics was the study of static water.

Electrostatics is about charge and about the attract–repel forces which electric charge creates.

In that case, only the hydraulics experts would realise that there's no such thing as "static water": the so-called "static" water is really just pressurised water. The experts would also know that "static water" can even flow along, since pressurised water need not remain still or "static". Hydrostatics still applies to water when it begins to flow. In a similar way, "static electricity" has everything to do with pressurised charge and nothing to do with "electricity at rest".

An imbalance of opposite charges

Here's another problem with the usual "static electricity" concept. First, think about everyday matter. Down inside its atoms, everyday matter contains equal numbers of positive and negative charges (protons and electrons) which are very close together. Are these charges the "static electricity"? After all, they're static and unmoving, right? They sit there inside each atom. And each individual electron and proton carries a charge of "static electricity". Shouldn't we say that physical matter is partly *made* out of "static electricity"?

But if we say that matter is made out of "static", then where are the sparks and crackling noises? There aren't any. Where is the rising hair? There isn't any. This shows that the "staticness" is not an important factor. Instead, the most important factor is the *balance of opposite charges*. Inside matter, the positive and negative charges are *close together*, and so their effects cancel out. Even though matter is full of charges which are "static" and unmoving, there is normally no "static electricity" to be seen.

It's about an *imbalance* between opposite charges, not about staticness. Also, the presence of charged particles is not such an important factor, since matter is full of them even when no "static electricity" appears. We need separated, imbalanced particle populations before interesting things start to happen. Just having charged particles is not enough.

How can we fix the confusion? Easy. Don't call it "static". Instead, call it "charge imbalance". It's the *net electric charge* which is important. Or, put more simply, it is the *separation* between positive and negative particles which is the basis for "static electricity".

When quantities of protons are separated from electrons across a large distance, then we'll get sparks and rising hair. Call this "electric charge", not "static charge," since the imbalance remains the same even when the charges flow along very non-statically.

Whenever these opposite charges in matter are sorted out and separated into groups of positive and negative, then we say that "static electricity" has been generated. What does this have to do with the charges remaining still or static? Nothing!

In fact, if the charge imbalance can be made to flow along, it will still retain all of its unusual characteristics. It will still attract hair and lint and cause sparks, etc., even while it is flowing. This puts us into the ridiculous situation of talking about "static electricity" which moves!

It's unfortunate that the term "static electricity" has become so widely adopted as the name for these phenomena. If it had been called something else—"imbalanced electricity", for example—it wouldn't be nearly as misleading. It's easy to think about an imbalance which moves or stays still.

But it's impossible to visualise an *unmoving* substance which *flows.* And it's even more unfortunate that textbooks have widely adopted the misleading practice of stating that "static electricity is electricity which is static and unmoving". This is a lie, and is no less a lie when many textbooks say the same thing.

Reality is not determined by majority vote. No matter how many people agree otherwise, the emperor's clothes remain missing.

What we call "static electricity" also has another name: "high voltage". All of the familiar electrostatic phenomena which we encounter in everyday situations always involve voltages above 1,000 volts and ranging up to around 50,000 volts at the most.

If it attracts lint or raises hair, it's definitely over 1,000 volts. Rub a balloon on your head, and you generate tens of thousands of volts! This is *voltage without a current*.

Here's a way to think about it: pure electric current involves a *current with zero voltage*, while pure "electrostatic" phenomena involve *electrical voltages with zero current.* Scuff your feet on a carpet and you create a voltage difference of many thousands of volts between your body and the carpet. Study "static electricity" and you study voltage itself.

It would be wonderful if the term "static electricity" could be removed from the English language and replaced by "high-voltage electricity", or possibly by "separated charge" or "charge imbalance", or "the science of electrostatics".

Also, charge flow and charge imbalance can happen in the same wire at the same time.

Therefore, anyone who believes that "static" and "current" are two types of opposite, mutually exclusive electricity will forever remain hopelessly confused about the true nature of any electrical phenomenon.

Electric circuits

Electric currents are caused by voltage, and the voltage in a circuit is caused by the imbalances of charge which are present on the surface of the metal wires.

"Static electricity" is what makes circuits operate! Without the "static electricity" supplied by batteries or generators, modern electrical devices could not exist. This shouldn't be a big surprise, since voltage and electrostatics are intimately intertwined.

Here's another way to think about it: when you rub some fur on plastic, you generate many thousands of volts, while common batteries only generate a few volts. But both of these create surface charge imbalances. And both create electrostatic attraction and repulsion forces.

Without the "static electricity" supplied by batteries or generators, modern electrical devices could not exist.

It's the electrostatic forces which drive the charges through the wires in a circuit. Electric currents are pumped by "static electricity".

Friction doesn't cause electrification

So, "static electricity" is caused by friction? Wrong! "Static" electricity appears whenever two dissimilar insulating materials are placed into intimate contact and then separated. All that's required is the touching.

Chemical bonds are formed when the surfaces touch; and if the atoms in one surface tend to hold electrons more tightly, that surface will tend to steal charged particles from the other surface immediately as they touch. This causes the surfaces to become oppositely "charged": they acquire imbalances of opposite polarity. One surface now has more electrons than protons, while the other has more protons than electrons. When the surfaces are later separated, the regions of opposite charge imbalance also get separated. For example, when adhesive tape is placed on an insulating surface and then peeled off, both the tape and the surface will become electrified. No friction is required.

Another example: when a thin material passes between rollers, sometimes the material becomes electrified. The rollers become oppositely electrified. When newspaper passes between rubber rollers in a printing press, the paper becomes electrified and later on this can cause problems with cling and sparking.

This situation in a large newspaper press inspired Robert Van de Graaff to design his famous generator.

Friction is not required. However, if one of the materials is rough or fibrous and does not give a very large footprint of contact area, then the process of rubbing one material upon another can greatly increase the total contact area. Friction may also remove thin layers of oil or oxide, exposing a more pure surface beneath.

The peeling tape does not have to be rubbed in order to generate charge imbalance, but the hair does need to be rubbed by the balloon. But the rubbing is not the *cause* of electrification. Electrification can come about purely from contact.

Voltages and e-fields

"Static electricity" involves immense voltages. Again, using the example of two insulating surfaces that are adhered (or rubbed) together and later pulled away from each other, a very strong "electric field" appears between them, and it is this e-field that can raise hair, attract lint, etc.

In addition, this e-field is an example of pure voltage, or voltage without current. The strength of this e-field is incredibly large when compared to the voltage of batteries and of common electronic circuitry. It is many thousands of times stronger, sometimes hundreds of thousands of times stronger.

Everyday "static electricity" involves immense voltages. The tiniest "static spark" is caused by about 1,000 volts. Longer duration "car door sparks" and "doorknob sparks" can involve as much as 10,000 volts.

Electron build-up

So, is it a case of electron build-up? Not exactly. It is not a build-up of anything. It is an *imbalance* between quantities of positive and negative particles which existed beforehand. The electric particles were already there: they did not have to build up. It's an "uncancelling", an event which occurs between the large quantities of oppositely charged particles which were already present in matter.

Contact electrification is more like "stretched atoms" than anything else. If we could take some atoms and pull their electrons far away from their protons, we would have created an imbalance of charge or "static electricity".

It's true that during "frictional electricity" or contact electrification, it's *usually* only the negative electrons which are moved from one surface to the other. But this transferring of electrons then results in two areas of imbalanced charge, not one. As negative particles are pulled away from the positive particles, the positives and negatives are no longer near each other and are no longer able to cancel each other. Because of this, equal and opposite areas of imbalanced charge are always created during the uncancelling. If you take away a neutral object's electrons, you leave its protons exposed.

And although the negative charges did the moving, this doesn't mean the positive charges are unimportant. Before the charges are separated, there are equal quantities of positive and negative charges present together within the materials. The positives null out the negatives, and the negatives null out the positives. After the separation of the charges is complete, the positive charges are just as important as the negative. In one place you'll have more protons than electrons, and this place will have an overall positive charge. In the other spot you'll have more electrons than protons, for an overall negative charge in that region. You've not caused a "build-up of electrons": you've caused an imbalance, an uncancelling, a stretching apart, a separation of opposites which otherwise would cancel each other.

In fact, one appropriate term for static electrification is "charge separation". Think for a moment: if you put the positive and negative imbalances back together, where does the "build-up of electrons" go? Nowhere. There was no build-up there in the first place. Putting the two polarities of charge back together eliminates the imbalance and forms normal, uncharged matter again.

Electrostatics and matter

Actually, physical objects are *made* out of charge. We always talk of matter as if it only had passing relation to electrical effects. Yet if we look in detail into the nature of matter, we find physical substances made of molecules, made of atoms, made of positive and negative electric charge.

Matter is not electrical? No, quite the opposite. Electric charge is the major component of all atoms. Therefore, matter is made out of *cancelled electric charge*. If we cancel out some opposite charge by placing positive charge together with negative charge, do we get *nothing*? No. Instead, we get material substance. Positive protons plus negative electrons equals neutral atoms.

Physical objects normally have no charge? Wrong. The physical objects *are* the charge.

Matter is made out of *cancelled electric charge*... Positive protons plus negative electrons equals neutral atoms.

"Static electricity" is as common as matter. If you believe typical explanations of "static electricity", you will come to see "static" as a fairly rare phenomenon that has little connection with the rest of the world. Yes, yes, lightning is impressive, and copiers and laser printers are convenient; but if "static" didn't exist, the world wouldn't be much different, would it?

In fact, electrostatics is a bit more important than we commonly assume. Contrary to popular belief, standard "electric current" circuits are deeply connected with electrostatics. For one thing, *it is the electrostatic force that drives electric current!* "Voltage" is an electrostatic phenomenon; voltage is electrostatic fields. Without electrostatics, there could be no voltage, hence no current and no electrical devices.

It is totally wrong to build a false wall between "static" and "current": it's as silly as teaching that "pressure" and "movement" are two separate types of water. "Static" and "current" are two fields of study, not two substances or energies. They are subject areas which were created entirely by humans. They don't *really* exist separately in the real world.

"Static electricity" is important in many other places besides lightning, photocopiers and doorknob sparks. For example:

• Your muscles are driven by long-chain molecules which are forced to slide across each other. This sliding is performed by electrostatic attraction and repulsion between parts of the molecule, and so your muscles are electrostatic motors!

• Nerves function as tiny capacitors, with charge pumps to electrify them and ion gates to discharge them.

• When uranium atoms are hit by neutrons and their nuclei split, the main source of released energy is the repulsion between like-charged positive protons in the fragments of the nucleus. Therefore, nuclear reactors release the electrostatic energy of uranium nuclei. A plutonium bomb is actually a "static electric" repulsion bomb!

• Semiconductor electrostatics is essential to modern electronics. One type of transistor in particular, the FET or "field effect transistor", is purely an electrostatic device. Electrostatic fields within it are used to open and close the conductive channel which regulates current. Are these sorts of transistors rare? No. Every single transistor in the memory, CPU and IO chips of modern PCs are FET transistors. Most of the transistors in modern TVs and stereos are FETs. Few people realise that "static electric" devices have taken over the electronics industry, or that PCs are made from microscopic electrostatic components, or that all the data in all the computers all over the world are stored as tiny patterns of electrostatic charges.

• "ATP" is the fuel which drives living things, from bacteria to humans. One part of the 1997 Nobel Prize in chemistry was awarded to the researchers Boyer and Walker, who discovered how energy is placed into ATP. It turns out that ATP is assembled by an enzyme which is run by a tiny rotating electrostatic motor! The "spring" in each ATP is "cocked" by a little rotating molecular machine run by electrostatics. The reaction is reversible and ATP can drive the motor, changing it into an electrostatic generator. A typical human body contains around 10^{16} of these rotary electrostatic motors.

A big one next. The world is made of molecules, and molecules are atoms, and atoms are themselves composed of positively and negatively charged particles. Atoms are held together by electrostatic attraction. If matter is made of little "dots", then the "bars" that connect all the dots together are made of electrostatic fields. Also, atoms are connected to each other through chemical bonding, and chemical bonding is based upon electrostatic attraction–repulsion forces.

Without "static electricity", there would be no chemistry, no living things. Without "static electricity", solids and liquids would be gas, the molecules of the gas would fall apart into atoms, and the atoms would turn into separate electrons and nuclei. Without electrostatics, the entire universe would be a boring, featureless cloud of neutral-particle gas. Some people consider electrostatics to be boring. On the contrary, electrostatics is the very thing that lets this universe be an interesting place!

Ben Franklin's kite experiment

Many people believe that Ben Franklin's kite was hit by a lightning bolt, and this was how he proved that lightning is electrical. A number of books and even some encyclopaedias say the same thing. They are wrong. They have fallen victim to an infectious myth, an "urban legend of science", which is slowly spreading to more and more books. When lightning strikes a kite, the spreading electric currents in the ground can kill anyone standing nearby, to say nothing of the person holding the string!

Franklin wrote about "drawing down the lightning" from a thunderstorm. What he actually did was to show that a kite would collect a tiny bit of imbalanced electric charge out of the sky during the early parts of a thunderstorm, before lightning strikes became a danger. Feeble electric leakage through the air caused his kite and string to become electrified, and the hairs on the twine stood outwards. Twine is slightly conductive on a humid day, and the twine served as Franklin's "antenna wire". The twine was then used to electrify a metal key, and tiny sparks could then be drawn from the key. (A metal object is needed because sparks cannot be directly drawn from the twine. The twine is slightly conductive, but not conductive enough to allow sparking.) No noise, no big flash—just boring yet earthshaking science experimenting. The presence of sparks suggested to Franklin that some stormclouds carry strong electrical charges, and it *implied* that lightning was just a large electrical spark.

The common belief that Franklin easily survived a lightning strike is not just wrong, it is dangerous: it may convince kids that it's okay to duplicate the kite experiment as long as they "protect" themselves by holding a silk ribbon with a key tied in the middle.

Make no mistake: Franklin's experiment was extremely dangerous. He could have been killed at any moment. And if lightning had actually hit his kite, today he would be regarded as a colonial politician who was killed by stupidity, not as a famous scientist who founded a major new research area.

Many people believe that Ben Franklin's kite was hit by a lightning bolt, and this was how he proved that lightning is electrical. This is a myth, an "urban legend of science", which is slowly spreading to more and more books.

So what *is* "static electricity"?

1. *Static electricity is a field of science. Some people call it "electrostatics". Same thing.*

So, if static electricity is a kind of science, then it can't be made by generators. In a similar way, you can dissect a dead frog, but you'll never find any biology. And rocks don't contain any tiny pieces of geology. Remember: *hydrostatics* is the study of fluid pressure; *Newtonian statics* is the study of physical forces; and *electro - statics* is the study of charge, voltage and electrical forces. Where can we find static electricity? In physics books—and in buildings at the university!

2. *Static electricity is a set of events which humans have grouped together.*

Sparks and lightning are "static electricity", even though sparks and lightning are about the most dynamic things imaginable. Also, "dryer cling" is "static electricity". The cling effect—*that* is the electricity. After all, "electricity" can mean "a class of phenomenon", and having your socks stick to the back of your sweater is certainly a phenomenon. Where does "static electricity " come from? From human minds—same as with "weather" and "bureaucracy" and other classes of phenomenon.

3. *Static electricity is another word for high voltage.*

Whenever we have high voltage, we also have electrostatic attraction and repulsion. High voltage can attract lint or tiny bits of paper, and it can make hair stand up. With high voltage we also get long sparks, crackling noises, and blue glows and flashes. High voltage makes ozone—the stuff that gives that funny chlorine smell.

These things are the hallmarks of "static electricity", but they are never caused by the "staticness" of electric charges. Instead, they are caused by intense e-fields—another way of saying "high voltage". If you can scuff your shoes on the carpet and then zap people with your finger, then you've been charging your body to several thousand volts.

4. *Static electricity means an imbal - ance of electric charge.*

Electrically neutral matter contains closely spaced electrons and protons. The "positives" and the "negatives" are very close together, so their effects cancel out. That's why electrical phenomena don't seem obvious in the everyday world. But if we accidentally remove a bunch of electrons from their atoms and then put these electrons in a distant spot, we'll create a region of positive net charge. We'll also create an equal region of negative net charge. These imbalances of charge will surround themselves with intense e-fields.

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